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A QUESTION CONCERNING THE CREATION OF PLANE MAGNETIC FIELD BY AN ARRAY OF IDEALLY CONDUCTING WAVEGUIDES

by

V. V. Martsafey

EDITED TRANSLATION

FTD-ID(RS)T-1811-79 7 December 1979

MICROFICHE NR: FTD-79-C-001575

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English pages: 7

Source: Izvestiya Vysshikh Uchebnykh Zavedeniy, Radioelektronika, Vol. 11, Nr. 1, 1968, pp. 36-40

Country of Origin: USSR
Translated by: Victor Mesenzeff
Requester: USAMICOM
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

A QUESTION CONCERNING THE CREATION OF PLANE MAGNETIC FIELD BY AN ARRAY OF IDEALLY CONDUCTING WAVEGUIDES

V. V. Martsafey

This article shows the difficulty involved in creating a quasiplane field at small distances from the radiator. An estimate is given for an array of ideally conducting waveguides (from the standpoint of the field created by it) using the exact theory.

INTRODUCTION

At the present time, a problem often arises in the measurement equipment which deals with the creation of a quasiplane electromagnetic field, which is necessary for the measurement of a number of characteristics (radiation patterns, scatter diagrams, etc.). Quite frequently, this problem is solved by the most elementary method - by increasing the distance between the object being measured and the radiator to a value on the order of

(1) $$R \sim \frac{2D^2}{\lambda},$$

where D is the maximum dimension of the test antenna or the scatterer and λ is a wavelength [1].

Obviously, in many instances, this distance can prove to be very large.

A method was proposed in 1953 [2], which is based on the transformation of a spherical wave into a plane wave by means of a lens collimator, which made it possible to shorten the distance considerably, improve the sensitivity of the device, etc.

Two requirements can be imposed on the collimator:

a) there should be a minimal difference between the plane field and the field leaving the collimator; b) the reciprocal reflections between the collimator and the object being measured must be minimal.

When comparing the lens collimators with the mirror collimators, preference should be given to the former because, with all other conditions being equal, the field leaving the lens collimators is close to the plane field, since the diffraction phenomena taking place in the mirrors are expressed more clearly. It is also clear that the waves reflected of the test object, which do not converge in the focus of the lens (with small ε') "leave the game", and in symmetrical mirror collimators the energy of these waves spills over towards the object being measured. However, lens collimators also have a number of drawbacks, the principal of which are:

a) a significant, although relatively gradual, change in the amplitude of the field behind the lens;

b) oscillations in the field's amplitude during the preparation of the lens from a foam polystyrene, which are due to the heterogeneity of the material;

c) relatively large reciprocal reflections during the preparation of the lens from an optically homogeneous material with a considerable ε.

Several versions were proposed for the improvement of the collimator's properties, for example [3, 4]; however, judging by the literature, the problem of lens collimators cannot be considered as solved. Under these conditions, it would be expedient to estimate the capabilities of the arrays.

In this work we will evaluate the capabilities of a simplest, from the technological standpoint, array (but also the worsts with regard to the heterogeneity of the exciting field) - Waveguide arrays with well-conducting sides. In order to simplify this problem, we will examine a two-dimensional problem, having assumed, furthermore, that the sides of the waveguides are infinitely thin, while the conductivity is infinitely high.

DERIVATION OF BASIC RELATIONS AND AN ANALYSIS OF THE OBTAINED EXPRESSIONS

Many works have been devoted to the problems dealing with the study of arrays consisting of ideally conducting plates [5–8]; however, most of them were devoted to the examination of the problems dealing with a plane wave hitting the array. The radiation from an array was analyzed in [8] but only for the limited values of the period of the array.

We will make it our task to find a strict solution for the field of radiation of an infinite array of ideally conducting semi-infinite waveguides, which are excited in-phase by the wave H_{01} with an arbitrary array period (Fig. 1). In this case we will extend this method for solving the problem of radiation from the open end of the waveguide [9] onto an array of such waveguides*.

Using the Gaussian system of units and discarding, everywhere, the time factor exp $(-i\omega t)$, we obtain the following expression for the vector potential describing the field in an infinite array of waveguides excited in-phase by the wave H_{01}:

$$A_x(y, z) = \frac{\pi i}{c} \int_0^{\infty} [\ldots H_0^{(1)}(k\sqrt{(y-(2n+1)a)^2+(z-\xi)^2}) + \ldots + H_0^{(1)}(k\sqrt{(y-a)^2+(z-\xi)^2}) \ldots + H_0^{(1)}(k\sqrt{(y+(2n+1)a)^2+(z-\xi)^2}) \ldots] \times J_x(\xi)\, d\xi, \tag{2}$$

where $J_x(\xi)$ is the surface density of the current.

We note that

$$E_x = ikA_x;\ H_y = \frac{dA_x}{dz};\ H_z = -\frac{dA_x}{dy};\ E_y = E_z = H_x = 0.$$

Using the boundary condition

$$E_x = 0 \text{ when } y = \pm(2n+1)a;\ n = 0;\ 1;\ 2;\ 3;\ \ldots,$$

---

* The fundamentals of this work stem from the report made by an author on the diffraction of waves at the II All-Union Symposium held in Gor'kiy (1962). As it was revealed at the symposium, using the same method, earlier, L. B. Tartakovskiy solved the problem dealing with an array of waveguides. However, to the best of his knowledge, a strict solution for the radiation field with an arbitrary period is presented and discussed for the first time.

we obtain the basic integral equation

$$\int_0^{\infty} \{\ldots 2H_0^{(1)}(k\sqrt{(nd)^2+(z-\xi)^2})+\ldots+2H_0^{(1)}(k\sqrt{d^2+(z-\xi)^2})+ \\ + H_0^{(1)}(k|z-\xi|)\} J_1(\xi)d\xi = 0. \tag{3}$$

Using the method described in [9], it is possible, departing from (3) and the condition of absence of the conductivity current outside the plates, to obtain the following system of differential equations:

$$\left.\begin{aligned} &\int_{-\infty}^{+\infty} e^{iwz} L(w)F(w)dw = 0, \text{ when } z>0 \\ &\int_{-\infty}^{+\infty} e^{iwz} F(w)dw = -Ae^{-ihz}, \text{ when } z<0 \end{aligned}\right\}, \tag{4}$$

where A is the amplitude of the wave incident on the aperture; h is a longitudinal wave number of this wave; $F(w)$ is the Fourier transform of the surface density of the current of the reflected wave; $L(w)$ is the Fourier transform of the kernel of the integral equation (3).

Since the system of functional equations (4), which descibes the fields created by an array of plane waveguides, differs from the system of the functional equations describing the fields of a solitary plane waveguide, in essence, only by the form of the function $L(w)$ [and, consequently, $F(w)$], we will omit the calculation operations similar to those in [9].

It is possible to establish that

$$L(w) = (w^2-h^2)L_1(w)L_2(w) \tag{5}$$

and

$$L_1(-w) = L_2(w) = -\frac{-i\Psi_2(w)}{\sqrt{k-w}\,(w-h)\varphi_2(w)}, \tag{6}$$

where $L_1(w)$ is the function, which is holomorphic in the upper half-plane Im $\geqslant$ 0 and which does not have zeros there; $L_2(w)$ is the function, which satisfies the same conditions in the lower half-plane $\mathrm{Im}\, w < 0$.

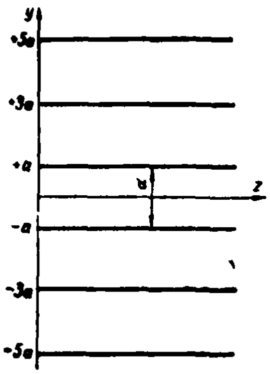

Fig. 1.

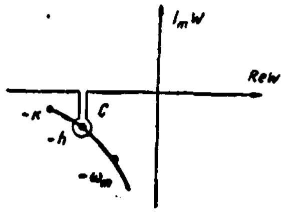

Fig. 2.

The functions $\varphi_2(w)$ and $\psi_2(w)$ have properties similar to those of $L_2(w)$, and they are given in [9].

Following [9], we find a solution for (4) in the form

$$F(w) = -\frac{A}{2\pi i}\cdot\frac{2hL_2(-h)}{(w^2-h^2)L_2(w)},$$

on the basis of which we obtain the following expression for the vector potential:

$$A_x(y,z) = \frac{\pi i}{c}\int_0^{\infty}\sum_{n=-\infty}^{+\infty} H_0^{(1)}\left(k\sqrt{(y-(2n+1)a)^2+(z-\xi)^2}\right)\int_C e^{iw\xi}F(w)\,dw\,d\xi$$

(contour C is shown in Fig. 2).

After transforming this expression, we obtain

$$(7)\qquad A_x(y,z) = \frac{2AhL_2(-h)}{c}\int_C \frac{e^{iwz}(\cos vy)\,\varphi_2(w)\sqrt{k-w}}{(w+h)\,\Psi_2(w)\,v\left(\sin\frac{vd}{2}\right)}\,dw,$$

where $v = \sqrt{k^2-w^2}$, $\operatorname{Im} v > 0$.

To find the radiation field, we close the contour C with a semicircumference in the lower half-plane, replace the infinite products in $\varphi_2(w)$ and $\psi_2(w)$ with the products of N factors (N>>1), we obtain the following expression after the use of the residue theory and transformation:

$$A_x(y,z) \simeq \Phi(k,d)\left\{\frac{[\exp(-ikz)]\left[\exp\left(i\frac{q}{2N}\right)\right]}{(h-k)\prod_{m=1}^{N}\left(1-\frac{q}{\gamma_m}\right)\prod_{m=1}^{N}\left(1+\frac{q}{\Gamma_m}\right)}+\right.$$

$$+\sum_{\nu=1}^{N}\frac{\left[\exp\left(-i\frac{2\pi\gamma_\nu z}{d}\right)\right]\left[\cos\frac{2\pi\nu y}{d}\right]\left[\exp i\frac{\gamma_\nu}{2N}\right]}{\left(h-\frac{2\pi\gamma_\nu}{d}\right)\left(k-\frac{2\pi\gamma_\nu}{d}\right)\prod_{m=1}^{N}\left(1+\frac{\gamma_\nu}{\Gamma_m}\right)}\times$$

$$\times\frac{1}{\left(1-\frac{\gamma_\nu}{\gamma_1}\right)\left(1-\frac{\gamma_\nu}{\gamma_2}\right)\ldots\left(1-\frac{\gamma_\nu}{\gamma_{\nu-1}}\right)\left(\frac{d}{2\pi\gamma_\nu}\right)\left(1-\frac{\gamma_\nu}{\gamma_{\nu+1}}\right)\ldots\left(1-\frac{\gamma_\nu}{\gamma_N}\right)}\Bigg\}. \quad (8)$$

The following designations are used in (8):

$$q=\frac{d}{\lambda};\ \gamma_m=\sqrt{q^2-m^2};\ \Gamma_m=\sqrt{q^2-(m-0{,}5)^2};\ h=\sqrt{k^2-\left(\frac{\pi}{d}\right)^2}.$$

From an analysis of (7) and (8) we can draw the following conclusions:

1. With any q, $A_x(y, z)$ is finite.

2. With $0.5<q<1$ the array forms a plane wave traveling along the normal from the array and the fields, which attenuate exponentially and which become negligibly small at a short distance from the aperture (when q is not very close to 1).

We note that this property of the array has been known for a long time. However, the metal-laminated lenses were designed with a distance between the plates of less than $\lambda (q<1)$, mainly, to make the lens more compact (for which it is necessary that the coefficient of refraction be significantly different from unity); although, from the approximate calculations, it is known that when $q>1$, the level of side lobes increases [10].

3. The numerical calculations performed on an electronic digital computer, with N=75 and q=1.06; 1.19; 1.31; and 1.44, have shown (with an accuracy up to the calculation and result-processing error): a) the oscillations in the field's amplitude beyond the array (at distances, when it is possible to disregard the fields which attenuate exponentially) are periodic and the period increases with an increase in q; b) for all the q listed, the ratio of a maximum value of the field's amplitude to the minimum value is equal to 9.

4. It is clear that such an enormous heterogeneity of the field beyond the array, when $q>1$, makes them virtually unsuitable for the creation of a quasiplane field.

Based on what has been said above, when evaluating the arrays of waveguides with the sides which conduct well, it should be noted that only arrays with $q<1$ are suitable for the creation of a quasi-plane field. However, even in this case, one should take into account the fact that the reciprocal reflections can be large (see the graph for the reflection coefficient in [7, 8]). Thus, the possibility that such arrays have to be used with various space attenuators is not excluded.

All this points to the limited capabilities of the arrays of well-conducting waveguides, designed to generate a quasiplane field.

BIBLIOGRAPHY

1. Куюмджан, Питерс, Требования к расстоянию при измерениях радиолокационного поперечного сечения, ТИИЭР, 1965, 53, 8, 1057.
2. Mentzer J. R., The use of dielectric lenses in reflection measurements, PIRE, 1953, 41, № 2, 252.
3. Ковалев В. П., Некоторые методы формирования плоской электромагнитной волны в лабораторных условиях, Радиотехника и электроника, 1962, 7, № 1, 71.
4. Кинбер Б. Е., Цейтлин В. Б., Об измерении параметров антенн в поле плоской волны, создаваемой коллиматором, Радиотехника и электроника, 1965, 10, № 7, 1190.
5. Carlson J. F., Heins A. E., The reflection of an electromagnetic plane wave by an infinite set of plates, I, Quarterly Appl. Mathematics, 1947, 4, № 4, 313.
6. Heins A. E., Carlson J. F., The reflection of an electromagnetic plane wave by an infinite set of plates, II, Quarterly Appl. Mathematics, 1947, 5, № 1, 82.
7. Lengyel B. A., The reflection and transmission at the surface of metal-plate media, J. Appl. Phys., 1951, 22, № 3, 265.
8. Whitehead E. A. N., The theory of parallel-plate media for microwave lenses, PIEE, 1951, 98, № 52, 133.
9. Вайнштейн Л. А., Дифракция электромагнитных и звуковых волн на открытом конце волновода, Изд-во «Советское радио», 1953.
10. Фрадин А. З., Антенны сверхвысоких частот, Изд-во «Советское радио», 1957.

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